A Structural Analysis of Global Corn and Soybean Markets from 2006 – 2017

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Abstract

This paper strives to analyze the driving factors of the monthly average prices of corn and soybeans between 2006 and 2016. The Global Food crisis of 2007 and 2008 subjected millions of people around the globe to increased levels of food scarcity. A wide array of academic studies have focused on the geopolitical and economic events of this time in an attempt to identify what caused such a rapid and dramatic increase in agricultural commodity prices. This paper in particular focuses on analyzing the biofuel policy implemented by the United States and other countries, with the intention of discovering a price relationship between agricultural and energy markets.

The following analysis includes the use of structural vector autoregressive (SVAR) models to analyze factors that contribute to the price determination of corn and soybeans. These models utilize a structural form that is representative of widely supported economic theory. The variables included in both models are the United States Dollar exchange rate, global output, global stocks, and previously identified linkages amongst gasoline and biofuel prices.

Results indicate that the monthly global prices of both corn and soybeans are highly affected by the value of the U.S. dollar, and the relationship amongst gasoline and biofuel prices. Surprisingly global output, and global stocks for each commodity are relatively insignificant in the determination of monthly average prices.

Biographical Sketch

Angelo Manzo was born to Robert and Phyllis Manzo in the spring of 1995. He grew up in the bustling ocean side community of Toms River along New Jersey's Atlantic Coast. As an only child, Angelo enjoyed the company of his parents, close family, and a number of loyal pets. Much of his time was spent with that of a good book and amongst his favorites were literary classics that included the Adventures of Tom Sawyer and The Life and Opinions of Tristram Shandy,Gentlemen. Throughout his formative years and into early adulthood Angelo has remained passionate about politics, economics, and baseball. The countless hours spent on a baseball diamond both with his father and various teams played an integral part in the development of his hard work ethic and will to succeed.

Angelo attended Purdue University where he completed his undergraduate education, having studied Agricultural Economics. Angelo has worked both in Chicago and Washington D.C. for the Chicago Mercantile Exchange and the United States Department of Agriculture. Upon the completion of his graduate education he will have obtained his Master of Science degree from Cornell University's Dyson School of Applied Economics. Ever the adventurous individual he looks forward to what challenges and opportunities life will bring forth in the future.

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Section 1

Introduction

"Millions of lives depend on the adequacy of the policy response to the terrible problems of hunger and starvation in the modern world."
- Amartya Sen

Perhaps no other industry has been more intimately related to the growth and prosperity of human kind than agriculture, and perhaps no other demographic is more susceptible to agricultural price shocks than the poor. This was highly evident at the height of the global food crisis in 2007, when as a result of rising commodity prices, the number of individuals subject to malnourished dietary conditions increased by 75 million (FAO 2008).

One such individual was a proud hardworking Ethiopian farmer, Mulualem Tegegn. Mulualem was forced to remove his grandchildren from school to work on the farm, and sold all of his livestock as a source of income. Instead of planting seeds to be cultivated and sold for profit, his family ate them, because food had become too expensive. The Tegegn family would not return to a state of food security until 2009 following intense government intervention and a stabilization of commodity prices. This return to normalcy meant that for the first time in two years Mulualem's grandchildren woke up in the morning not to work in the vegetable fields of Ethiopia, but instead walked to school in search of a much brighter future (Marshall, 2009).

Mulualem's story is joint one of the many instances of food insecurity that developed as a result of record high commodity prices. The World Bank reported in April 2008 that the heightened cost of food subsequently left thirty-three countries in a state of heightened risk for civil unrest. At the time, the poorest fifth of American's families only spent 16 percent of their income on food, while those in Nigeria, Vietnam and Indonesia spent 73, 65 and 50 percent respectively (The New York Times, 2008). While the economic burdens of elevated costs to food may not be felt as strongly in developed nations, the global nature of agricultural markets raises questions and concerns for policy makers and consumers world wide.

Agricultural markets have undergone rapid growth expanses since the 1970's, including intense levels of globalization, supported by a reduction of transaction costs, trade and investment barriers. These developments have created a highly competitive market that supports a wide array of international products and trade (FAO, 2008). Such an inexplicable linkage on a global scale, establishes agricultural commodity prices as those that are subject to major structural alterations, which result from a multitude of contributing factors. Commodity price movement can be attributed to the ever exceedingly complex interactions of monetary policy, energy, heightened caloric demand, consumer preference, trade policy, and the biological conditions affecting agricultural production. Consequently, a careful evaluation of such factors is imperative when working towards the implementation of successful government policy that ensures a safe and reliable global food system that is capable of achieving conditions that support ever growing demand (Abbott, Hurt, Tyner 2009).

The global economy and the agriculture industry were subjected to a number of social, political and economic alterations within the past two decades. Biofuel regulations, the value of the U.S. dollar, crude oil prices, levels of production, heightened global demand, and market speculation have all been evaluated to determine their effect, if any, on commodity prices.

This paper strives to identify the components that play a vital role in the ever evolving dynamic that is agricultural price discovery, specifically analyzing market conditions for global corn, and soybean markets. A plethora of academic and private studies have attempted to identify key components contributing to the rapid increase and subsequently volatile fluctuations of food commodity prices, particularly evaluating the economic conditions preceding and during the global food crisis. Subsequent sections of this paper will focus on relevant literature while identifying the ways in which this study contributes to the academic analyses. Structural vector autoregressive models (SVAR) are used to evaluate the effects that macroeconomic and commodity production factors have on the global prices of corn and soybeans.

Section 2

Review of Literature

Conflict rooted in Middle Eastern politics, particularly the establishment of the Organization of Petroleum Exporting Countries (OPEC), served as a transitory event in the process of commodity price discovery from segregated markets to complex global systems. The Oil Embargo of 1973 had rippling effects throughout the global economy, as shortened supplies and long gas station lines throughout the western world caused the price of crude oil to quadruple in just three months (Solomon et al., 2007). As a result many western nations, particularly Brazil and the United States began the development of alternative fuels as a matter of national security, in an attempt to reduce high levels of foreign energy dependence. Such alternatives included the production of biofuels.

A biofuel can be defined as a liquid, gas, or solid fuel who's primary composition is that of biomass. There are a wide variety of biofuels ranging from vegetable oils to biohydrogen, although the most commonly used are ethanol and biodiesel. Ethanol, primarily comprised of corn, and biodiesel, primarily sourced from oil seeds, require large swaths of agricultural land and significant amounts of each respective crop to be produced (Demirbas, 2010). As biofuel production places an ever-growing demand on agricultural production and industry resources, the role that biofuels play in terms of commodity price determination will continue to grow. Fluctuations in market conditions such as the global food and global energy crisis outlined above often serve as a catalyst for dynamic shifts in the structure of an economic sector, and biofuels, particularly ethanol and biodiesel, have served as a solution to numerous socioeconomic and environmental challenges (Cremonez et al. 2015).

The implementation of legislation and the beginning of mass biofuel production in the United States was intended to address a number of environmental, economic, and social issues which included a reduction in emissions, a decreased dependence on foreign energy, and an increase in farm income (deGorter, Drabik, and Just 2013). Policies such as the 2005 Renewable Fuel Standard have created a strong integration amongst agricultural and energy commodity markets and the global food crisis of 2007 is widely discussed in the literature as a direct result of the aforementioned implementation of biofuel policy.

This thesis will serve to evaluate a number of determining factors that affect the global price of corn and soybeans. We will focus on they key policies that have established energy and agricultural market integration, as well as a macroeconomic conditions represented by the United States Dollar exchange rate, and the global production and storage of both corn and soybeans.

2.1 The Development of Agriculture and Energy Markets Linkages

The agricultural industry has made astonishing advancements in terms of mechanized production since the advent of the first gasoline powered tractor in 1892. Prior to the integration of biofuels and the highly correlated markets of agriculture and energy, crop prices were highly influenced by the input cost of oil (Baffes 2007). An examination of Figure 2.1.1 and Figure 2.1.2 demonstrates that a correlation of any noticeable significance amongst corn and crude oil prices, coupled with heightened volatility, is not apparent until late 2006. Figures 2.1.3 and 2.1.4 show similar trends for soybean and crude oil prices as well.

Since the 1970's the United States and Brazil have been the leading producers of fuel ethanol. The United States Government had passed numerous forms of legislation in support of biofuel development yet by 2005 ethanol accounted for only 2.8 percent all motor fuels in vehicles (Solomon, 2010). Such legislative programs included the Small Ethanol Producer Tax Credit, which supported a biofuel industry that used 7 percent of the United States corn crop to produce fuel ethanol in 2001 (Schnepf, Yacobucci 2013).

The development of the biofuel complex in operation today can primarily be attributed to the desire of the U.S. Government to reduce dependence on energy imports and to quell levels of hazardous emissions. The enactment of the Energy Policy Act of 2005 established the first Renewable Fuel standard, or RFS1. The RFS1 instituted a production mandate requiring a minimum of 4 billion gallons of fuel ethanol to be used in 2006, increasing to 7.5 billion gallons by 2012. This initial biofuel mandate was expanded two years later under the Energy Independence and Security Act of 2007, also known as RFS2. RFS2 established new requirements of biofuel consumption, establishing the use of 9 billion gallons of biofuels in 2008, increasing to 36 billion gallons in 2022.

By 2013 the blend wall made the initial targets of RFS1 and RFS2 unrealistic. The blend wall is in reference to the existing limit of ethanol content as a percentage of finished motor gasoline (E10), which is 10 percent. After 2005 the demand for gasoline had been falling in response to increasing fuel prices and would continue through until 2014. In response to these conditions, proposals by the EPA in 2013 were made to reduce the RFS target for 2014. In 2015 the EPA raised the goal for renewable fuel content from 9.52 percent to 10.10 percent in 2016 (Baumeister Killian Ellwanger, 2017).

The implementation of the RFS programs gave light to a new market with guaranteed demand, subsequently raising the price of biofuel inputs in relation to their price without the mandate (Schnepf and Yacobucci, 2013). Furthermore, the RFS and established blend walls create both a price floor and ceiling for biofuel demand, which greatly affect the demand for U.S. corn, and soybeans. Supply shocks to these markets would also be met with a greater magnitude of price volatility under the RFS requirements (McPhail 2012). In addition to the RFS policies, state level bans on Methyl Tertiary Butyl Ether (MTBE) contributed to the rapid increase of ethanol demand. MTBE was a common and widely used input in the production of gasoline. However, MTBE is known to be a toxic water contaminate and ethanol became a commonly used substitute for MTBE in the production of gasoline by 2006. (Song, et al., 2006)

Most studies indicate a strong link amongst agriculture and energy markets, and the extent to which biofuels impact grain prices is still widely debated. In the United States over 40 percent of United States corn production is being utilized for the production of ethanol. Given that soybeans and corn can be grown on much of the same land, the subsequent increase in corn production came from land that could have been utilized in the production of soy and other crops. Mitchell 2008 has indicated that biofuel production was the primary driver of price increases since 2008. The identification of the linkages between energy biofuel and crop prices utilized in this paper were identified by in the book "The Economics of Biofuel Policy: Impacts on Price Volatility in Grain and Oilseed Markets" (Gorter, Harry de, et al. 2015) and will be discussed further in the following section.

Section 2.2 Other Factors

There are a number of factors that contributed to agricultural commodity price fluctuations in the 2000's. Zhang, 2010 indicates that large levels of income growth in China, India, and South America, have resulted in an increased amount of grain usage and a transition towards diets that have a high protein concentration. Coinciding with increasing income levels in developing regions there has been a global increase in the demand for energy, particularly oil (Hamilton, 2015).

Killian, and Hicks (2013) outline the role and importance of grain stocks in agricultural price determination. Widely discussed in the literature is that a sizeable reduction in commodity production will in turn result in a decline in that commodities stocks, with inventories being drawn down. Changing global weather patterns could also result in reduced grain production and increased global prices.

Global macroeconomic conditions are widely cited as common factor in the determination of agricultural commodity prices. The international nature of agriculture, particularly in the early 21st century makes agricultural commodity prices highly susceptible to global economic shocks. Evidence provided by Bailey and Chan indicate that both commodity cash and futures prices reflect the macroeconomic risks common to all types of asset classes. Fluctuations in monetary value have also been identified as a component in explaining the historical price movements of oil and other industrial commodities (Barsky, Kilian, 1993). Their paper demonstrates that monetary expansions and contractions generate a level of stagflation even in the absence of a commodity's supply shock, therefore suggesting that the relative importance of macroeconomic factors are greater than that of a commodity's supply conditions in the determination of price.

A number of papers in the literature utilize global real economic activity, described as a measure of global economic conditions (Kilian, 2009). This however fails to fundamentally capture the relationship between global macroeconomic conditions and the demand for an agricultural commodity. For this study we will evaluate the relationship between the United States dollar exchange rate and the price of both corn and soybeans. Figure 2.2.1 and Figure 2.2.2 identify the inverse relationship amongst corn, and soybean prices and the dollar exchange rate. A depreciation of the U.S. dollar increases global prices, as strengthening demand and a limit to the supply from non-U.S. dollar commodity consumers and markets takes effect (Baffes, Dennis, 2015). There has been evidence of linkages between real interest rates, exchange rates, and the price of agricultural commodities (Campbell, Frankel 2013). There is also strong evidence that the commodity price increases beginning in 2006 were impacted by low interest rates and a weak dollar (Enders and Holt,).

A combination of the aforementioned factors have contributed to the price volatility in agricultural commodity prices since 2006, yet the evolution of global energy and grain linkages are most likely the largest contributing factor.

Section 3

Econometric Analysis

Section 3.1 Methodology

The structural vector autoregressive (SVAR) models used in this study are estimated for the monthly global price of corn and soybeans, as reported by the United States Federal Reserve. These estimates are comprised of monthly time series data beginning in January 2007 and April 2007, until December 2016, for corn and soybeans respectively. For each equation, monthly indicators are utilized to control for the dynamic effects of seasonality within global agriculture and energy markets. The length of this time series is dictated by the necessity to evaluate how the prices of corn and soybeans responded to shocks following the implementation of biofuel policy in the United States. Arguments could be made that an analysis of shorter time series, intended to examine individual run-ups and declines in commodity prices, would better explain individual shocks. However, a longer time series allows for a more robust estimation of the regression parameters.

This study is intended to empirically quantify five components in identifying the monthly change in global commodity prices for corn and soybeans. The use of a structural vector autoregressive models (SVAR) is highly compatible with the aforementioned nature of agriculture commodity markets. Such models are widely used to analyze monetary, technical and fiscal shocks to a market (Teterin, Brooks, Enders 2016). The reduced form method, vector autoregression, was developed in the 1980's and is difficult to interpret unless the reduced form is linked to an economic model whereas the contemporaneous movements of each of the variables in these models are subject to an economic structure imposed by the SVAR (McPhail, 2016).

The six variable SVAR models used are based on the proposition that the monthly changes in corn and soybean price are determined by shocks in the macro economy (dollar exchange rate), global production, global stocks, and price linkages between crude oil, and biofules. Most global commodities, particularly oil and grains, are valued in US dollars but are purchased in the respective local currency. Therefore, commodity prices are inversely correlated to the value of the dollar. In an effort to capture the supply of global grain markets, monthly global output and stocks as reported in the United States Department of Agriculture's monthly World Agricultural Supply and Demand Estimates, are incorporated. Instead of solely focusing on the price of crude oil and the production total of biofuels, this model captures the impact of these factors by including identified linkages from the book "The Economics of Biofuel Policy" amongst gasoline, biofuels, and grain prices. The link between ethanol and gasoline prices is based on the policy of a binding ethanol mandate.

This presumed linkage is represented by the following equation where P_e is the calculated price of ethanol. Based on the presumption of standard economic theory this equation assumes that fuel consumption and the distance traveled generates a level of utility for the consumer. The volumetric fuel tax charged to a gallon of fuel is denoted t, and λ is defined as the ratio of miles per gallon of ethanol to miles per gallon of gasoline, calculated to be .70, and P_G is the market price of gasoline. In order to incorporate a subsidy based on ethanol consumption, such as the U.S. blender's tax credit, the heightened cost of ethanol caused by increased demand from blenders is accounted for by the addition of t_c. This allows for a representative wholesale price of ethanol, and is represented by equation 1.

Equation 1

$$P_e = \lambda P_G - (1-\lambda)t + t_c$$

Figure 3.1.1 is a graph displaying the predicted price of ethanol compared to the actual global price of corn.

In an effort to establish the link between ethanol and corn prices, it is assumed that ethanol is being produced by perfectly competitive firms. The following equation identifies the relationship between the price of corn P_c and the price of ethanol P_e.

Equation 2

$$P_c = \frac{\beta}{1-\alpha\gamma}(P_e - C_0) + \frac{\theta}{1-\alpha\gamma}P_{CO}$$

In total, the 2.8 gallons of ethanol that are produced from one bushel of yellow corn is identified by β. γ denotes the bushels of dried distillers grains with solubles (DDGS) per bushel of yellow corn used as animal feed, and α represents the relative price of DDGS and yellow corn. The extraction of corn oil from DDGS has become an increasingly common practice and is accounted for by identifying the pounds of corn oil produced from one bushel of corn as θ and P_{CO} as the price of corn oil.

In a similar mode of analysis to the SVAR model used for global corn price analysis, a similar model is constructed for global soybean prices with minor adjustments to account for the use of biodiesel instead of ethanol. The soybean model seeks so identify the response of monthly global soybean price to shocks in the dollar exchange rate, global output and stocks. In addition, the linkages amongst crude oil, biodiesel and soybean prices are included and are identified as follows.

Equation 3

$$P_{bd} = \lambda P_g - (1 - \lambda)t + t_c$$

The above equation defines P_{bd} as the predicted price of biodiesel establishing a link between biodiesel and diesel markets. λ represents the ratio of miles per gallon of biodiesel to miles per gallon of gasoline, and is calculated to be .913. P_g is again the price of gasoline. The volumetric fuel tax is denoted t, and a blenders tax credit is incorporated into the model with the addition of t_c.

Equation 4

$$P_{sb} = \beta_1 P_{so} + \beta_2 P_{sm}$$

This equation establishes the link between soybean price and the price of biodiesel. The amount of soybean oil obtained from crushing one bushel of soybeans is represented by β_1, and the amount of soybean meal obtained from crushing one bushel of soybeans is identified by β_2. The price of soybean oil and the price of soybean meal are denoted by P_{so} and P_{sm} respectively.

For the SVAR analysis it is first necessary to determine if there is a long-run relationship amongst the monthly time series for each variable. Johansen's test for cointegration is used, yielding a result in which the maximum eigenvalues are less than the 5 percent significance level. This indicates that it is not necessary to use a Vector Error Correction Model, and both the corn and soybean data sets can be tested using a SVAR. In order to ensure that the time series variables of each data set are stationary, in each of the variables are tested in first difference form. An augmented Dickey Fuller test is utilized, and ultimately rejecting the null hypothesis, and the existence of a unit root. Each of the variables are therefore confirmed to be stationary at the 5 percent significance level. In order to determine the appropriate lag length a modified log likelihood ratio test is conducted and the SBIC and HQIC information criterion confirms the utilization of zero lags for both corn and soybean models.

The representation of each SVAR equation is as follows.

Equation 5

$$A_0X_t = \propto + \sum_{i=1}^{p} A_iX_{t-i} + \varepsilon_t$$

In the case of the global corn model X_t is equal to the dollar exchange rate, global corn output, global corn stocks, the gasoline-ethanol link, and the ethanol corn relationship $(dxr_t, gco_t, gcs_t, pep_t, pcp_t)$. Similarly, in the case of the global soybean model X_t is equal to the dollar exchange rate, global soybean output, global soybean stocks, the diesel-biodiesel price link, and the biodiesel-soybean price relationship $(dxr_t, gbo_t, gbs_t, pbdp_t, psbp_t)$. A_i represents the lagged effects of the monthly endogenous variables, A_0 captures the the contemporaneous interactions amongst the models variables and the lag order is represented by P. ε_t is a vector of serially and uncorrelated structural innovations.

Equation 6

$$X_t = A_0^{-1}\alpha + \sum_{i=1}^{p} A_0^{-1} A_iX_{t-i} + A_0^{-1} + e_t$$

By imposing a recursive structure on the SVAR models it is assumed that not all of the variables will respond to each other contemporaneously. We assume global commodity output, stocks, or the interactions amongst the price relationships of fuels and grains do not affect the dollar exchange rate. Additionally the structure of this model indicates that the price relationship between biofuels and grains is dependent on the U.S. dollar exchange rate, global grain outputs, stocks and the cost of fuels. Based on this economic intuition the following matrices use the previously outlined structural parameters.

Equation 7

$$e_t = \begin{pmatrix} e_t^{dxr} \\ e_t^{gco} \\ e_t^{gcs} \\ e_t^{pep} \\ e_t^{pcp} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} * \begin{pmatrix} e_t^{dollar\_exchange\_rate} \\ e_t^{global\_corn\_output} \\ e_t^{global\_corn\_stocks} \\ e_t^{gasoline\_ethanol\_link} \\ e_t^{ethanol\_corn\_link} \end{pmatrix}$$

Equation 8

$$e_t = \begin{pmatrix} e_t^{dxr} \\ e_t^{gbo} \\ e_t^{gbs} \\ e_t^{psb} \\ e_t^{gbp} \end{pmatrix} = \begin{pmatrix} a_{11} & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix} * \begin{pmatrix} e_t^{dollar\_exchange\_rate} \\ e_t^{global\_bean\_output} \\ e_t^{global\_bean\_stocks} \\ e_t^{diesel\_biodiesel\_link} \\ e_t^{biodiesel\_bean\_link} \end{pmatrix}$$

Section 3.2 Corn Model Results

In order to evaluate the response of global corn price to shocks in the dollar exchange rate, global supply, and the linkages between crude oil and biofuel production impulse response analysis is used. The graphs of each impulse response functions (irf), presented in Appendix A, identify the response of the global corn price to each shock over the course of a twelve month period. As expected, the dollar exchange rate is inversely correlated with the global price of corn. The negative response is statistically significant, peaking at month one, and remains persistent in the system until month five as indicated by figure A1, in appendix A. Figure A2 and A3 represent global supply factors, identified as global corn output and global stocks are insignificant in the model and demonstrate that the integration of energy markets and agriculture have reduced the role of fundamental production factors in terms of price discovery. Global corn price has the largest response to the calculated price of ethanol displayed in figure A4, P_e which is representative of the price linkage between gasoline and ethanol. The identified negative relationship can be interpreted in the following way. Since P_e is a representation of a consumer's willingness to pay for gasoline, it can be implied that a high price of gasoline reduces the demand for travel, and therefore a reduced demand for ethanol and subsequently corn. Figure A5 shows how global corn price responds to the ethanol and corn price relationship. P_c, being a predicted price of corn based on the corn-ethanol relationship is the strongest positive component in the determination of global corn price. This relationship peaks at about month 2 and eventually fades by month five.

In order to identify the importance of each shock in the determination of monthly price fluctuations in global corn price, forecast error variance decomposition is calculated based on the estimates of the SVAR. Forecast error variance decomposition (FEVD) allocates the forecast error variance of each variable to the individual shock, creating a quantitative measure representing shocks from each respective variable.

Table A1 presents a time horizon of 12 months, and reports the percentage of each variance of the error made in forecasting global corn price resulting from a specific shock at a specific time along the horizon. The results from this test show that about 70% of variation in global corn price is determined by shocks to the corn market, or factors that are not represented by shocks in exchange rates, global production and supply, and gasoline-ethanol and ethanol-corn linkages. At one month the dollar exchange rate accounts for thirteen percent of global corn price variation, while output and stocks explain less than 1 percent each. Additionally the linkage defined in the gasoline-ethanol price relationship explains about 1.5 percent at one month, whereas the defined ethanol-corn link accounts for 14 percent of the variation.

Section 3.3 Soybean Model Results

Impulse response analysis will again be applied to examine the response of global soybean price to shocks of the dollar exchange rate, global soybean output, global soybean stocks, and the linkages established amongst diesel and biodiesel as well as biodiesel and soybeans. The impulse response functions presented in Appendix B identify the response of global soybean price in response to the aforementioned variables over a period of twelve months. In conjunction with economic theory and the results produced by the corn model, the dollar exchange rate has an inverse correlation to the global price of soybeans. Similar to the corn model, shocks in global soybean output are insignificant and have no identifiable effect on soybean price. Shocks to global stocks have an inverse relationship with global soybean price, indicating that heightened levels of inventory negatively affect price. The diesel-biodiesel relationship exhibits similar patterns to that of the gasoline-ethanol linkage, and theory would suggest that a higher price in diesel would result in reduced demand for diesel fuel. This would subsequently cause a reduction in the demand for biodiesel and therefore soybeans as well. The response of global soybean price to the diesel-biodiesel link peaks in the first month and gradually dies out in month three. The biodiesel-soybean price link differs from the ethanol-corn relationship, in that it sharply declines reaching a negative shock response in the first month, before becoming positive at month two and eventually becoming insignificant after month three. The inconsistencies of this particular irf could indicate that the model is capturing a level of endogeneity, and therefore the biodiesel-soybean relationship is not being identified accurately.

Forecast error variance decomposition is again used to identify the relative importance of each shock in determining the monthly change in global bean prices and is outlined in table B5. The table reports the percentage of the variance of the error made in forecasting soybean prices at a specific point on the time horizon between one and twelve months. FEVD shows that at month one the biodiesel-soybean price link explains roughly 43 percent of monthly price variations. This shock explains the largest amount of price variations, whereas output and stocks explain roughly 1 percent. Shocks in the dollar exchange rate, and the diesel-biodiesel price relationship explain 18 and 2 percent respectively.

Conclusions

The structural vector autoregressive models used in this study measure the market shocks of global output, global stocks, the dollar exchange rate and linkages amongst energy and biofuel markets, and the subsequent response of global corn and soybean prices. Using the dollar exchange rate to account for global macroeconomic trends, global output and stocks to represent supply, and the identified relationships between biofuels and grain prices, one can identify just how crucial biofuel implementation has been in agricultural markets over the past decade.

Corn and soybeans both are highly susceptible to shocks in the dollar exchange rate, however soybeans are more so possibly because of a higher prevalence in international markets. Price fluctuations for both grains are highly responsive to shocks in the relationship between global energy prices and biofuels. However, the biodiesel-soybean price relationship explains the price of soybeans at a level that is 3.5 times greater than the role the ethanol-corn linkage explains in terms of monthly corn fluctuations. Surprisingly fundamental information like output and stocks, factors that are widely considered when evaluating grain prices, have little to no effect on the monthly price fluctuations. This clearly demonstrates the prevalence that biofuel policy and global macroeconomic conditions have on the determination of agricultural prices.

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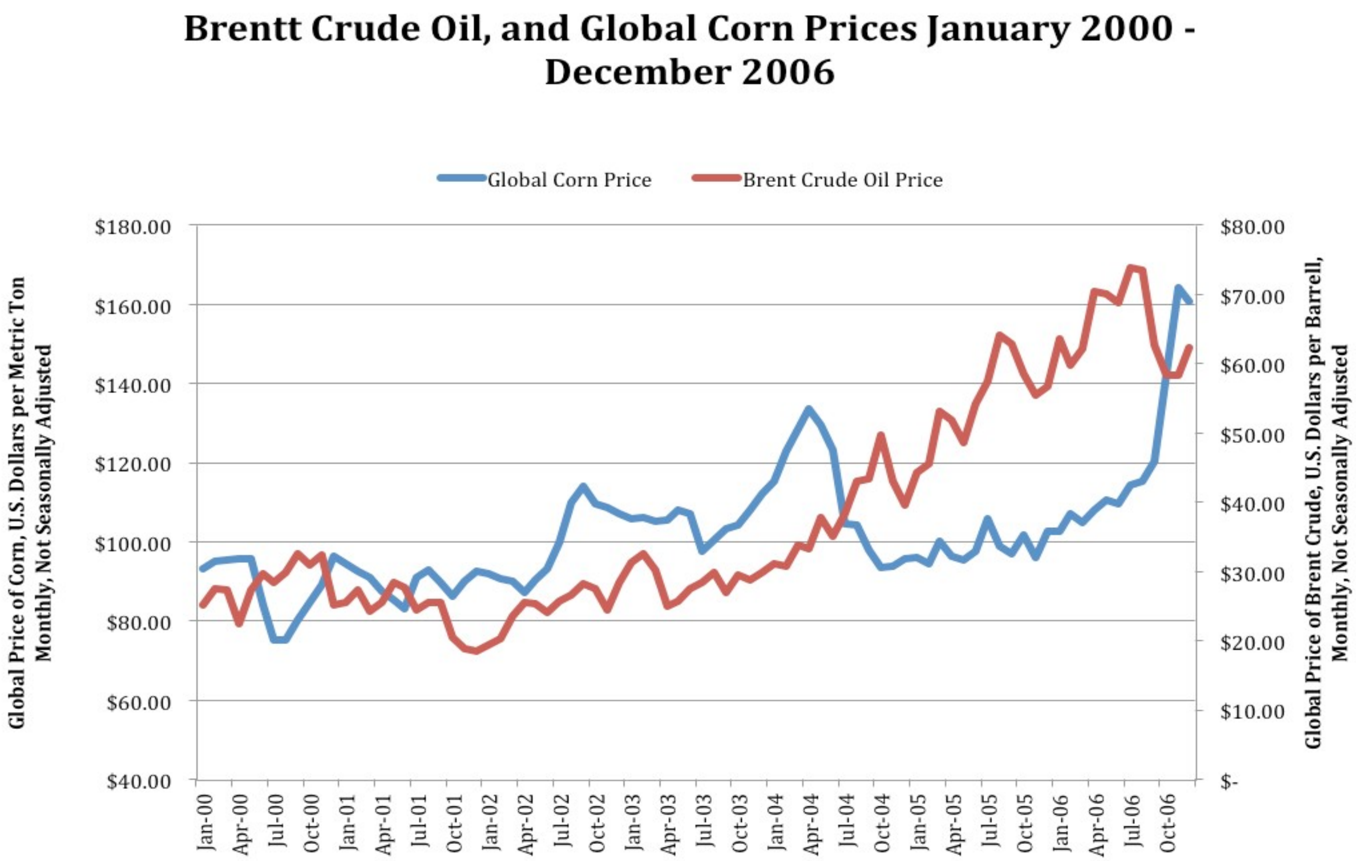


Figure 2.1.1 Crude Oil and Global Corn Prices January 2000 – December 2016
Source: Federal Reserve Economic Data, Economic Research Division Federal Reserve Bank of St. Louis

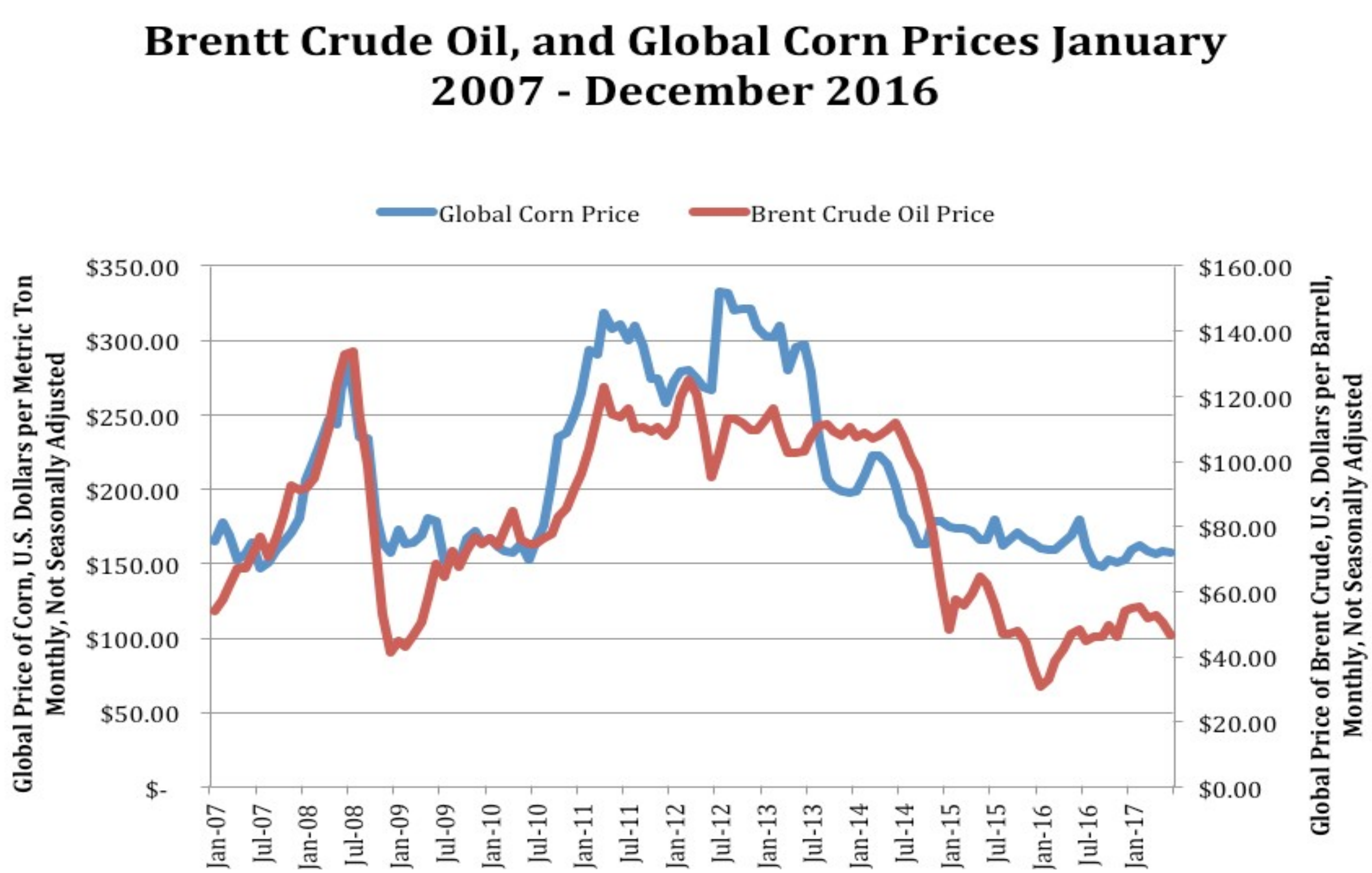


Figure 2.1.2 Crude Oil and Global Corn Prices January 2007 – December 2016
Source: Federal Reserve Economic Data, Economic Research Division Federal Reserve Bank of St. Louis

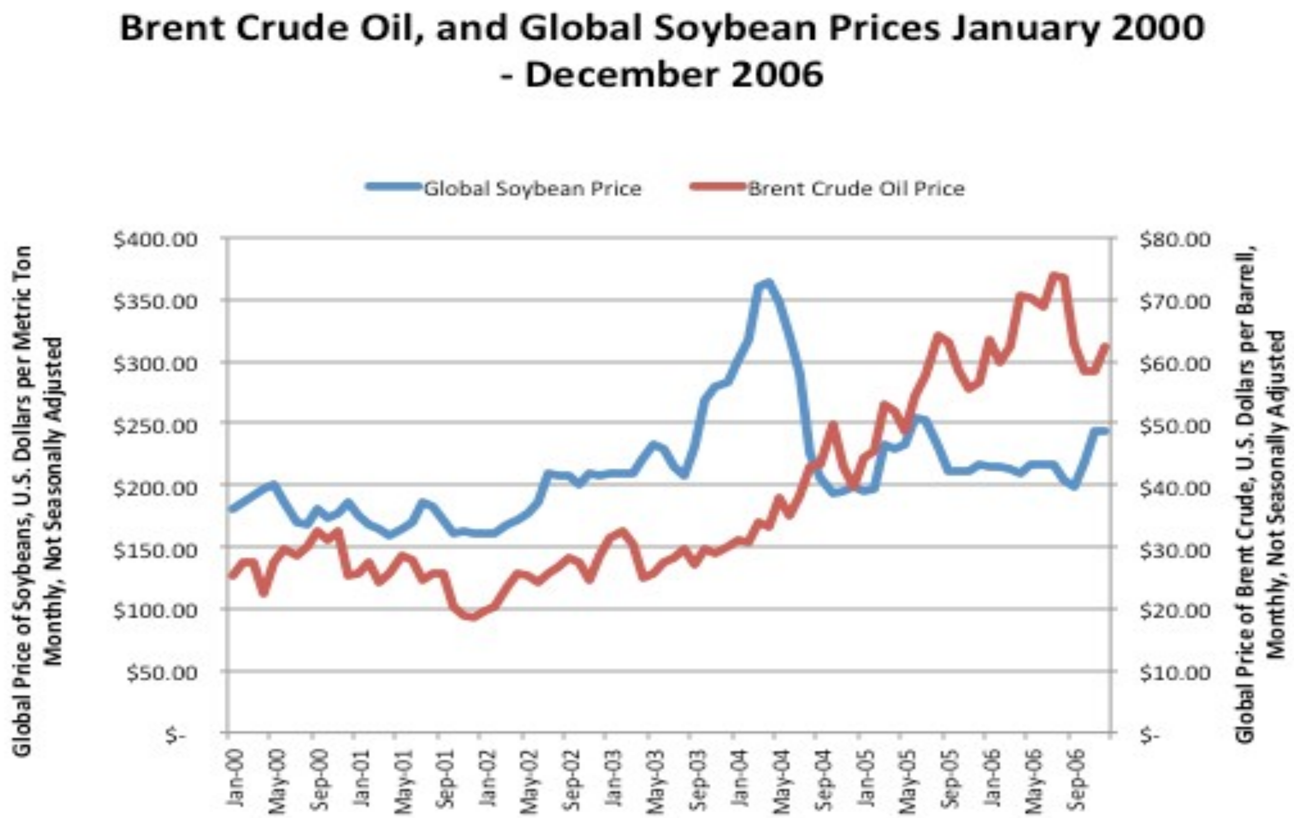


Figure 2.1.3 Crude Oil and Global Soybean Prices January 2000 – December 2006
Source: Federal Reserve Economic Data, Economic Research Division Federal Reserve Bank of St. Louis

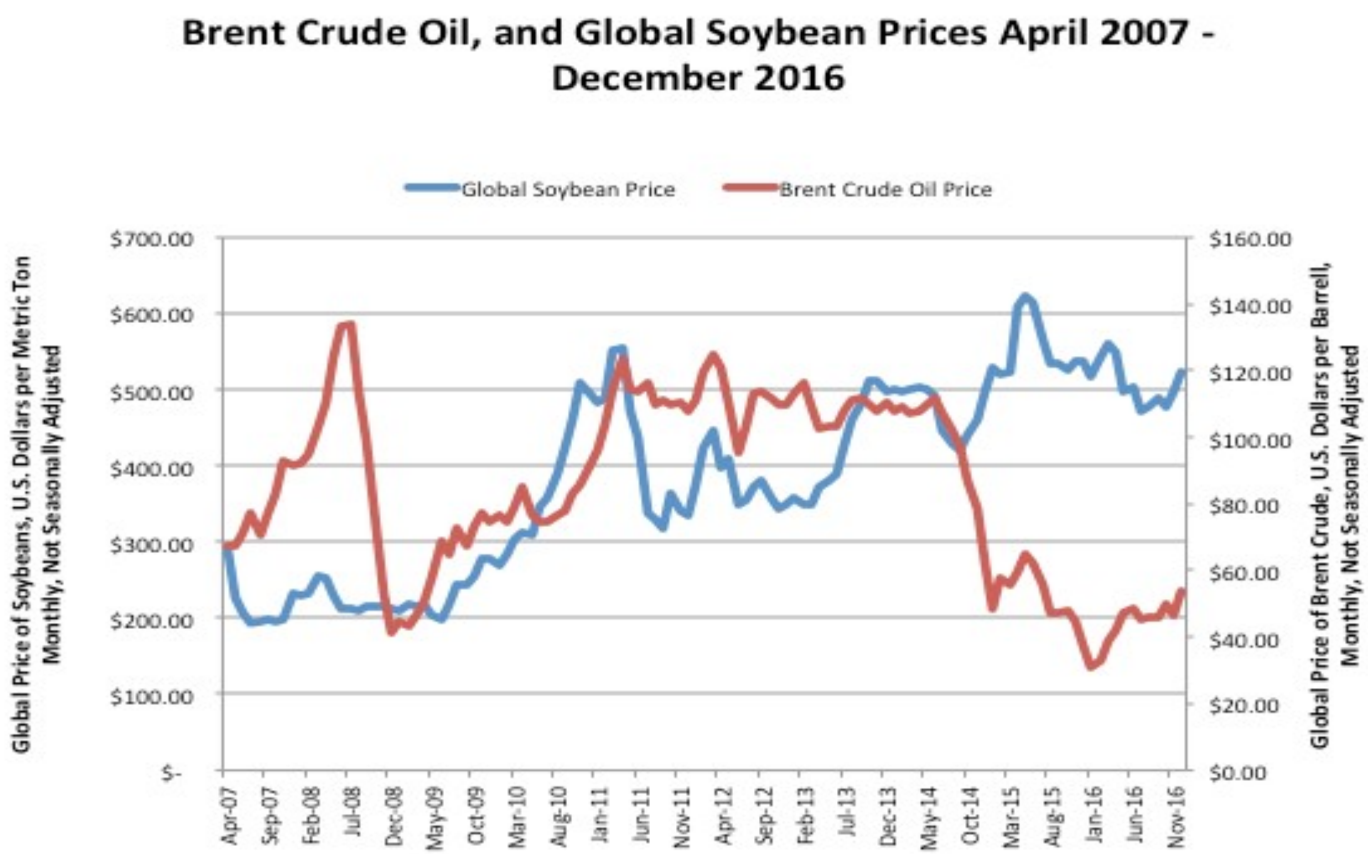


Figure 2.1.4 Crude Oil and Global Soybean Prices April 2007 – December 2016
Source: Federal Reserve Economic Data, Economic Research Division Federal Reserve Bank of St. Louis

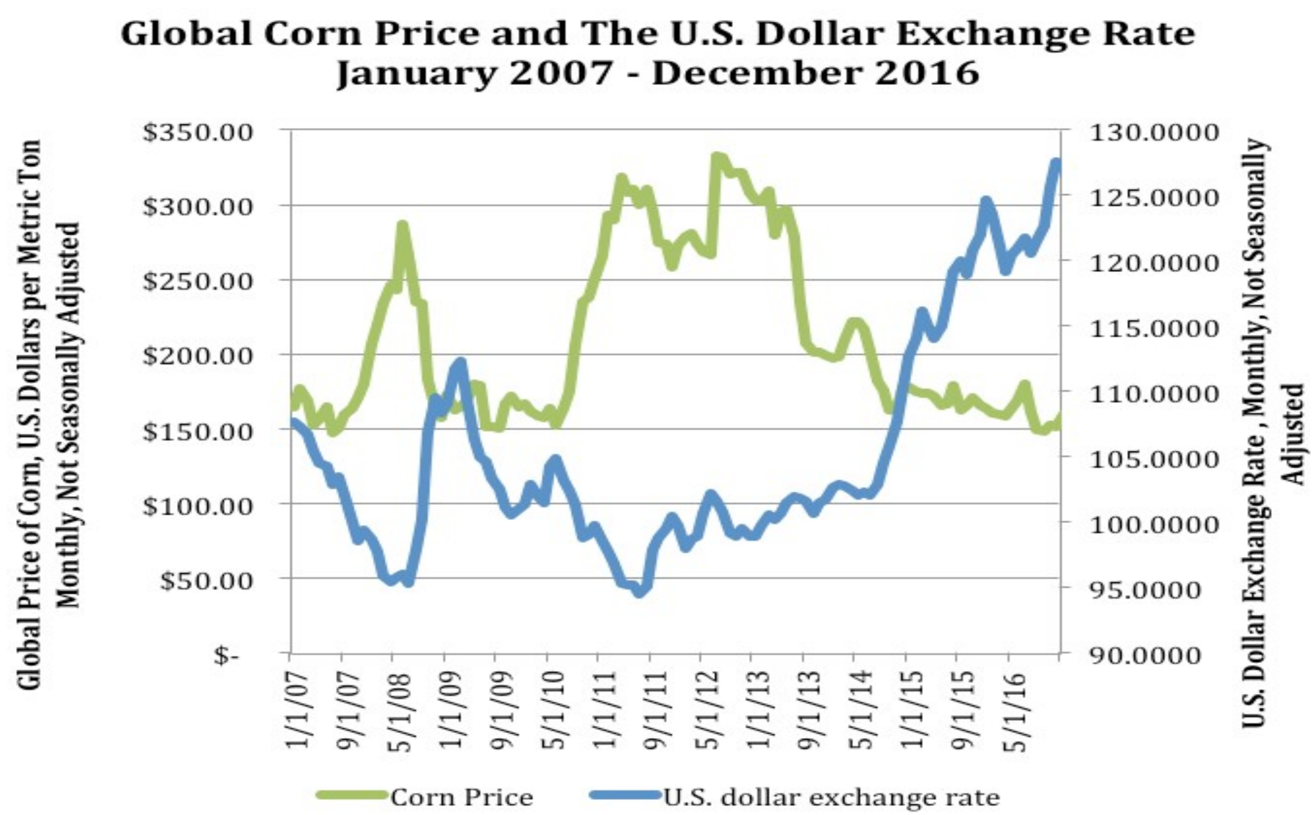


Figure 2.2.1 Global Corn Prices and the U.S. Dollar Exchange Rate January 2007 – December 2016
Source: Federal Reserve Economic Data Economic Research Service, Federal Reserve Bank of St. Louis

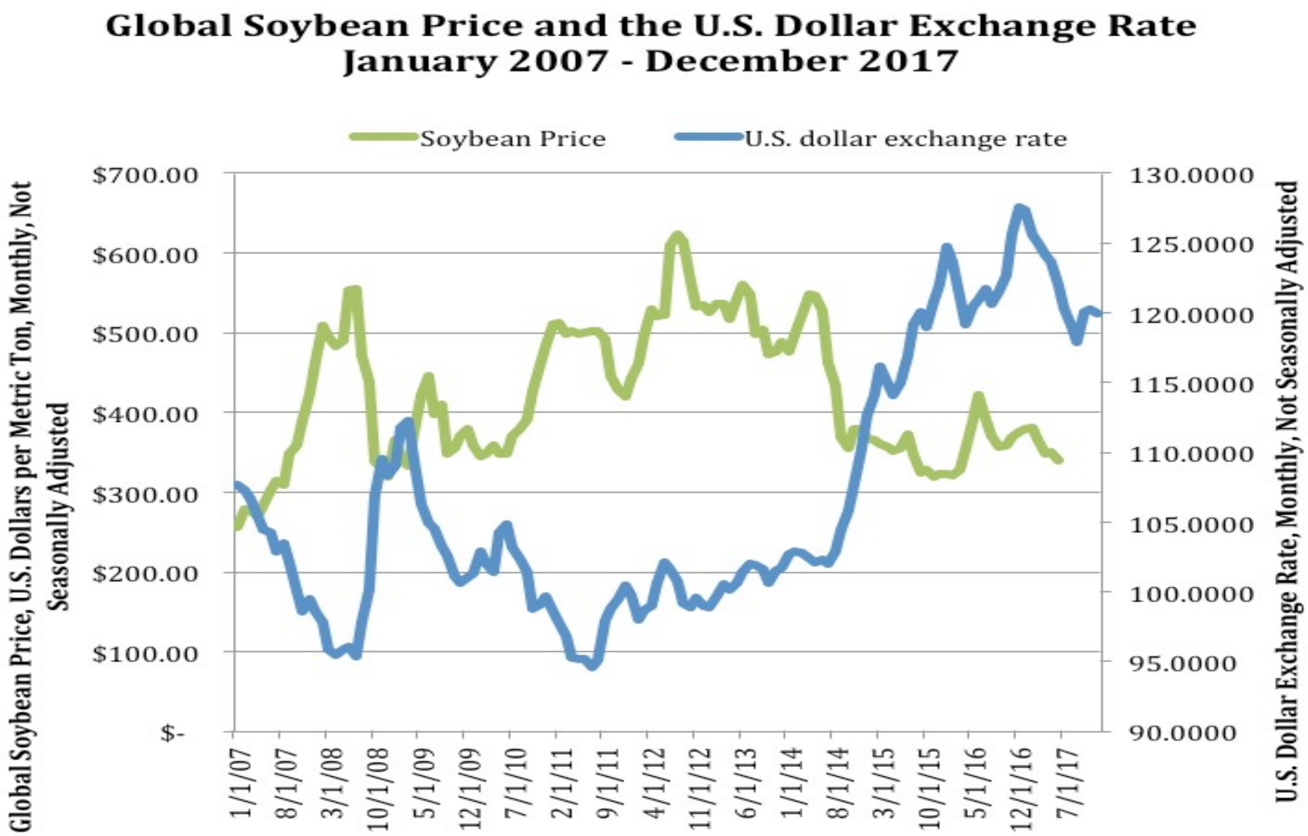


Figure 2.2.2 Global Soybean Prices and the U.S. Dollar Exchange Rate, January 2007 – December 2016
Source: Federal Reserve Economic Data, Economic Research Service, Federal Reserve Bank of St. Louis

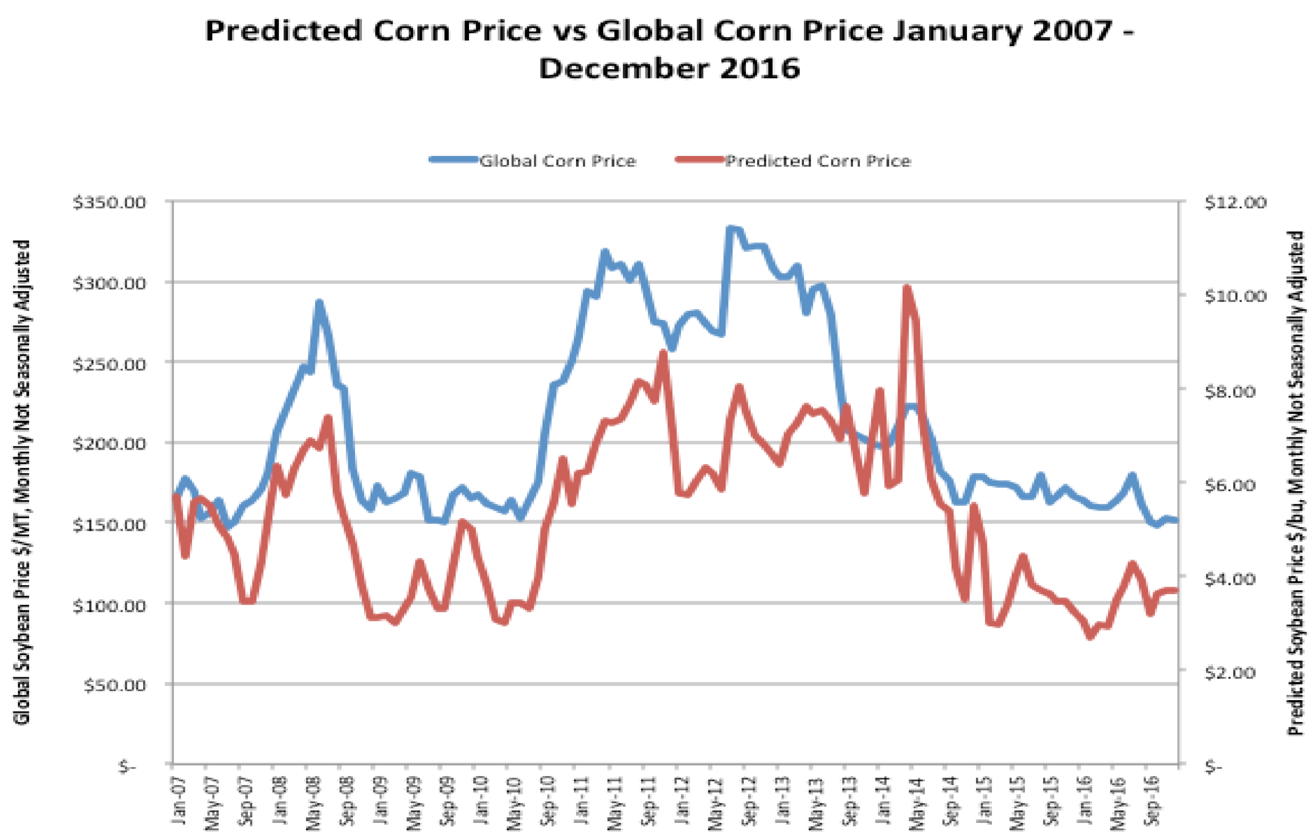


Figure 3.1.1 Predicted Corn Price $/bu. vs Global Corn Price $/MT January 2007 – December 2016

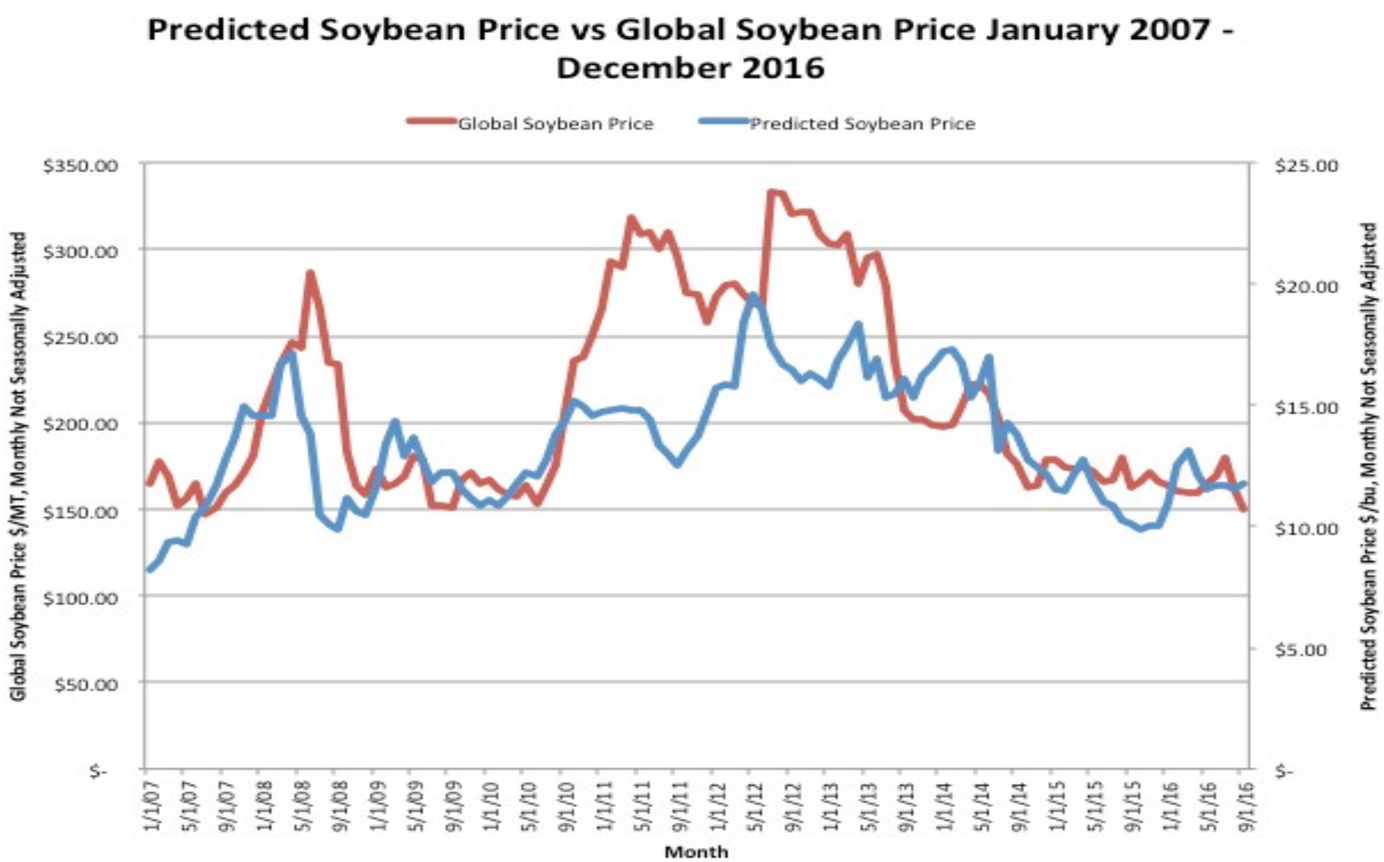


Figure 3.1.2 Predicted Soybean Price and Global Soybean Price, January 2007 – December 2016

Appendix A – Global Corn Model

Johansen Test for Cointegration

Corn Model
Trend: Constant
Sample: 2007􏰀2016
Lags: 2

Table A1

Maximum Rank	Parms	LL	Eigenvalue	Trace Statistic	5% Critical Value
0	30	$1340.0065	$	354.9175	68.52
1	39	$1289.7684	0.57944	254.4414	47.21
2	46	$1246.2358	0.52790	167.3762	29.68
3	51	$1205.9447	0.50076	86.7940	15.41
4	54	$1176.1865	0.40135	27.2776	3.76
5	55	$1162.5477	0.20955		

Augmented Dickey Fuller Test Corn Model – Dollar Exchange Rate

Table A2

Lags	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
12	-3.343	-3.558	-2.775	-2.501
11	-3.351	-3.558	-2.8	-2.525
10	-4.957	-3.558	-2.825	-2.549
9	-5.244	-3.558	-2.85	-2.572
8	-4.857	-3.558	-2.874	-2.594
7	-4.843	-3.558	-2.896	-2.615
6	-4.853	-3.558	-2.918	-2.635
5	-6.165	-3.558	-2.939	-2.654
4	-7.257	-3.558	-2.958	-2.672
3	-6.564	-3.558	-2.976	-2.688
2	-7.277	-3.558	-2.993	-2.703
1	-9.483	-3.558	-3.007	-2.716

Augmented Dickey Fuller Test Corn Model – Global Corn Output

Table A3

Lags	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
12	-3.343	-3.558	-2.775	-2.501
11	-3.351	-3.558	-2.8	-2.525
10	-4.957	-3.558	-2.825	-2.549
9	-5.244	-3.558	-2.85	-2.572
8	-4.857	-3.558	-2.874	-2.594
7	-4.843	-3.558	-2.896	-2.615
6	-4.853	-3.558	-2.918	-2.635
5	-6.165	-3.558	-2.939	-2.654
4	-7.257	-3.558	-2.958	-2.672
3	-6.564	-3.558	-2.976	-2.688
2	-7.277	-3.558	-2.993	-2.703
1	-9.483	-3.558	-3.007	-2.716

Augmented Dickey Fuller Test Corn Model – Global Corn Stocks

Table A4

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.658	-3.558	-2.775	-2.501
11	-4.344	-3.558	-2.8	-2.525
10	-4.305	-3.558	-2.825	-2.549
9	-4.572	-3.558	-2.85	-2.572
8	-4.302	-3.558	-2.874	-2.594
7	-4.996	-3.558	-2.896	-2.615
6	-4.754	-3.558	-2.918	-2.635
5	-5.619	-3.558	-2.939	-2.654
4	-5.627	-3.558	-2.958	-2.672
3	-6.053	-3.558	-2.976	-2.688
2	-7.586	-3.558	-2.993	-2.703
1	-10.962	-3.558	-3.007	-2.716

Augmented Dickey Fuller Test Corn Model – Predicted Ethanol Price

Table A5

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-2.219	-3.558	-2.775	-2.501
11	-2.192	-3.558	-2.8	-2.525
10	-2.348	-3.558	-2.825	-2.549
9	-2.834	-3.558	-2.85	-2.572
8	-3.152	-3.558	-2.874	-2.594
7	-3.769	-3.558	-2.896	-2.615
6	-3.932	-3.558	-2.918	-2.635
5	-4.321	-3.558	-2.939	-2.654
4	-3.641	-3.558	-2.958	-2.672
3	-4.457	-3.558	-2.976	-2.688
2	-5.263	-3.558	-2.993	-2.703
1	-5.571	-3.558	-3.007	-2.716

Augmented Dickey Fuller Test Corn Model – Predicted Corn Price

Table A6

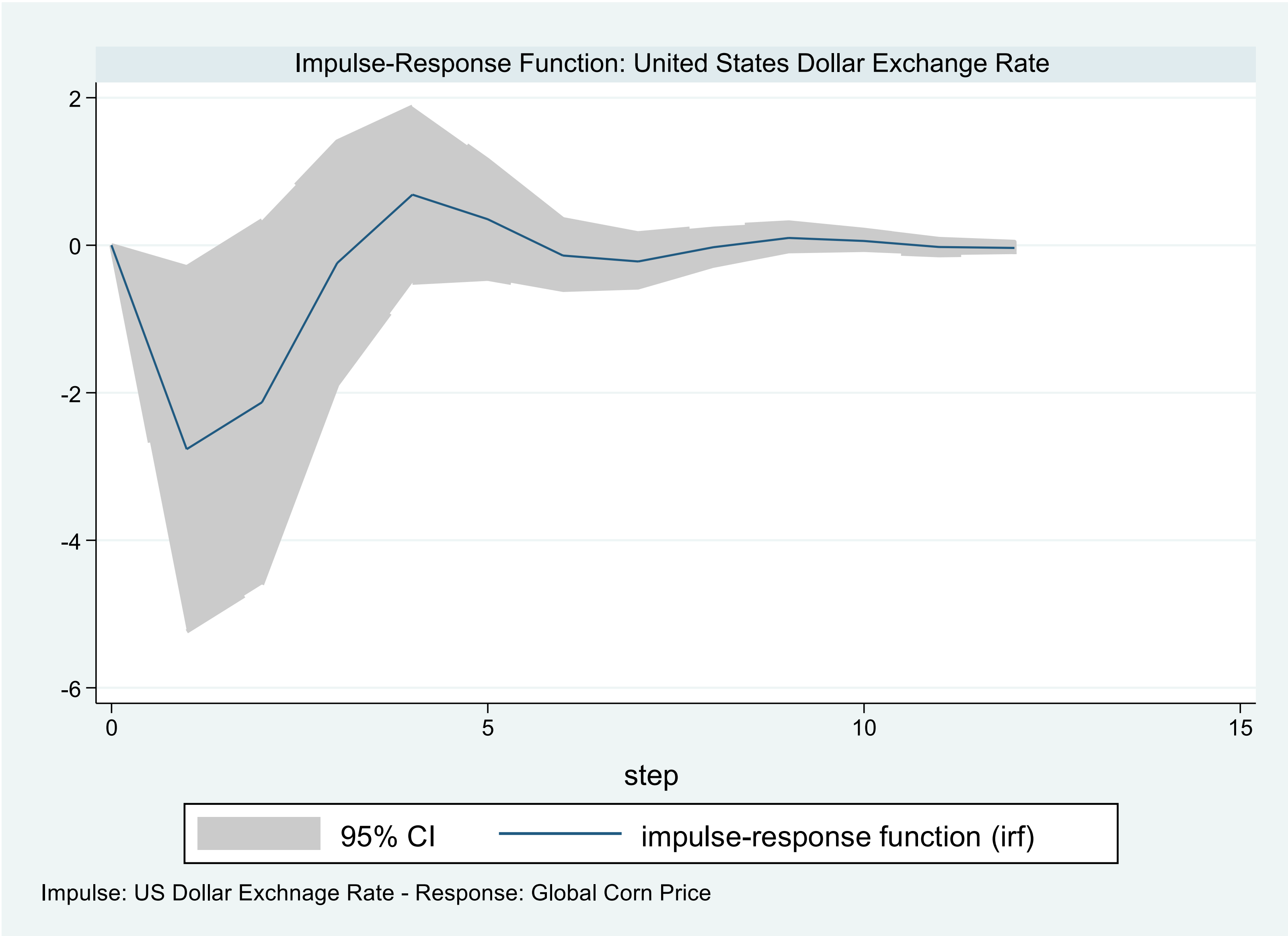
Lags	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
12	-1.804	-3.558	-2.775	-2.501
11	-1.921	-3.558	-2.8	-2.525
10	-2.02	-3.558	-2.825	-2.549
9	-2.275	-3.558	-2.85	-2.572
8	-2.304	-3.558	-2.874	-2.594
7	-2.311	-3.558	-2.896	-2.615
6	-2.919	-3.558	-2.918	-2.635
5	-2.971	-3.558	-2.939	-2.654
4	-3.251	-3.558	-2.958	-2.672
3	-3.623	-3.558	-2.976	-2.688
2	-4.45	-3.558	-2.993	-2.703
1	-7.378	-3.558	-3.007	-2.716

Augmented Dickey Fuller Test Corn Model – Global Corn Price

Table A7

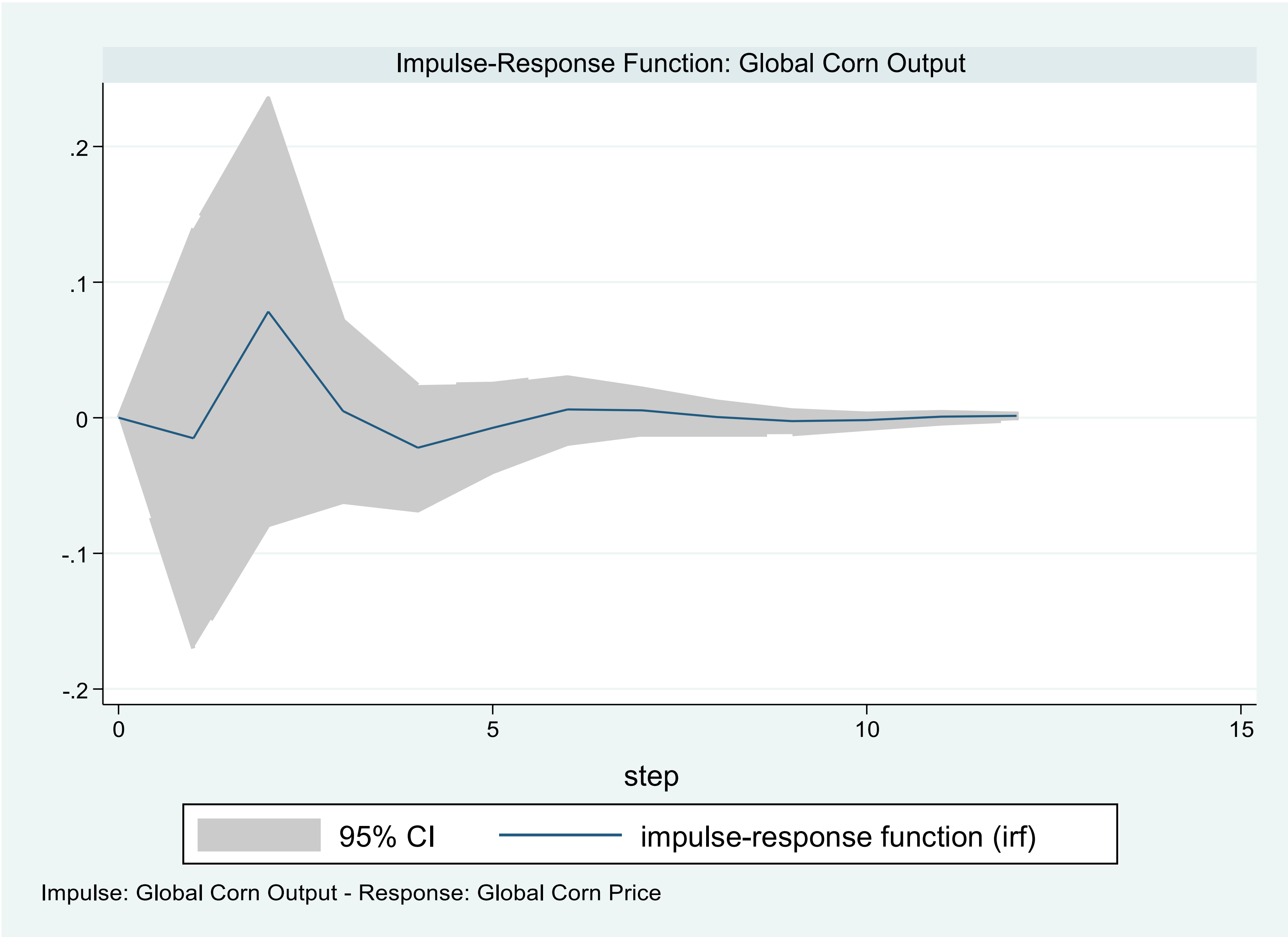
Lags	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
12	-2.916	-3.558	-2.775	-2.501
11	-2.576	-3.558	-2.8	-2.525
10	-2.454	-3.558	-2.825	-2.549
9	-3.072	-3.558	-2.85	-2.572
8	-3.35	-3.558	-2.874	-2.594
7	-3.474	-3.558	-2.896	-2.615
6	-3.654	-3.558	-2.918	-2.635
5	-3.92	-3.558	-2.939	-2.654
4	-3.974	-3.558	-2.958	-2.672
3	-4.259	-3.558	-2.976	-2.688
2	-4.838	-3.558	-2.993	-2.703
1	-5.851	-3.558	-3.007	-2.716

Figure A1



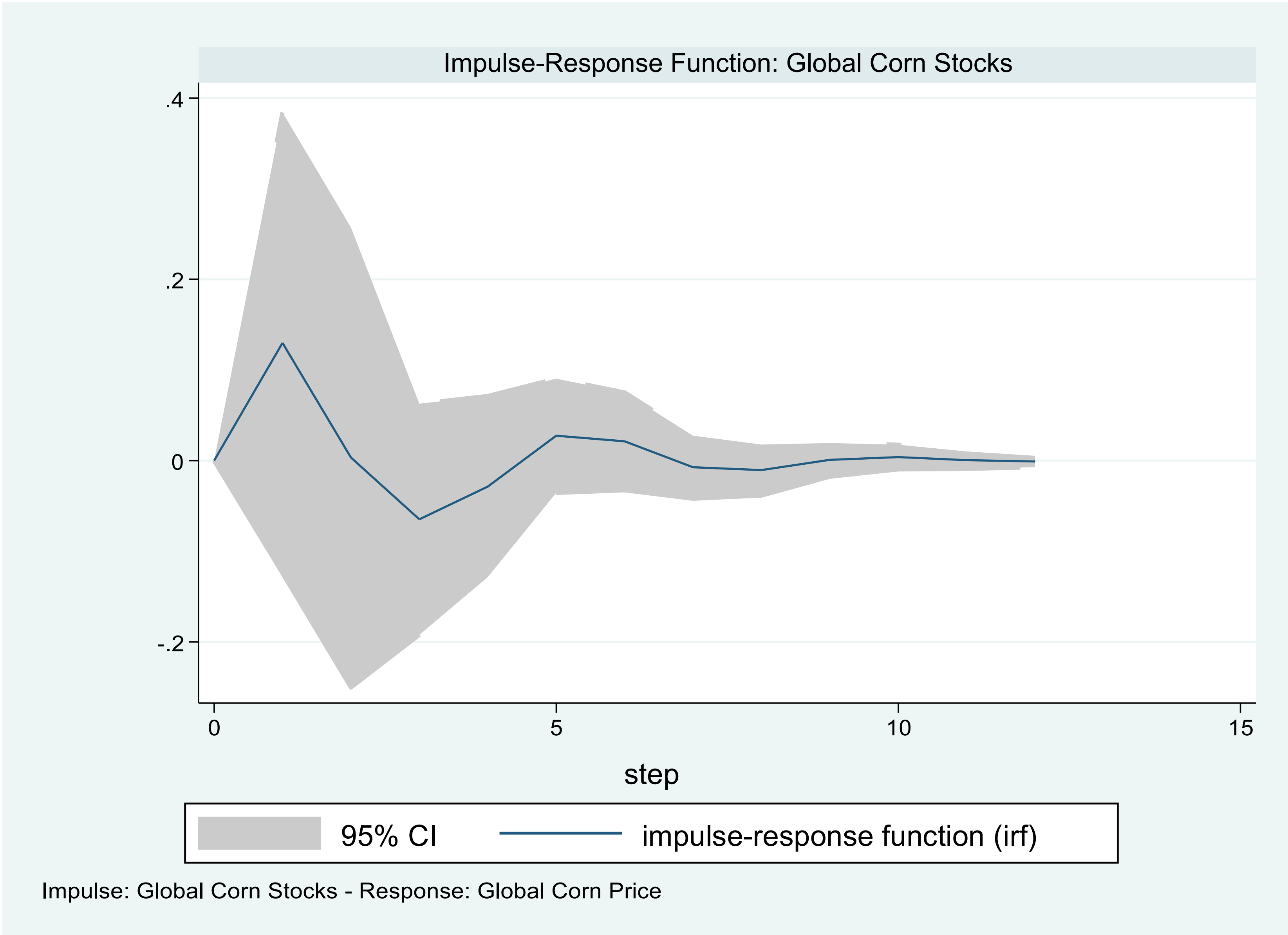
Impulse-Response Function: United States Dollar Exchange Rate
2
0
-2
-4
-6
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: US Dollar Exchnage Rate - Response: Global Corn Price

Figure A2



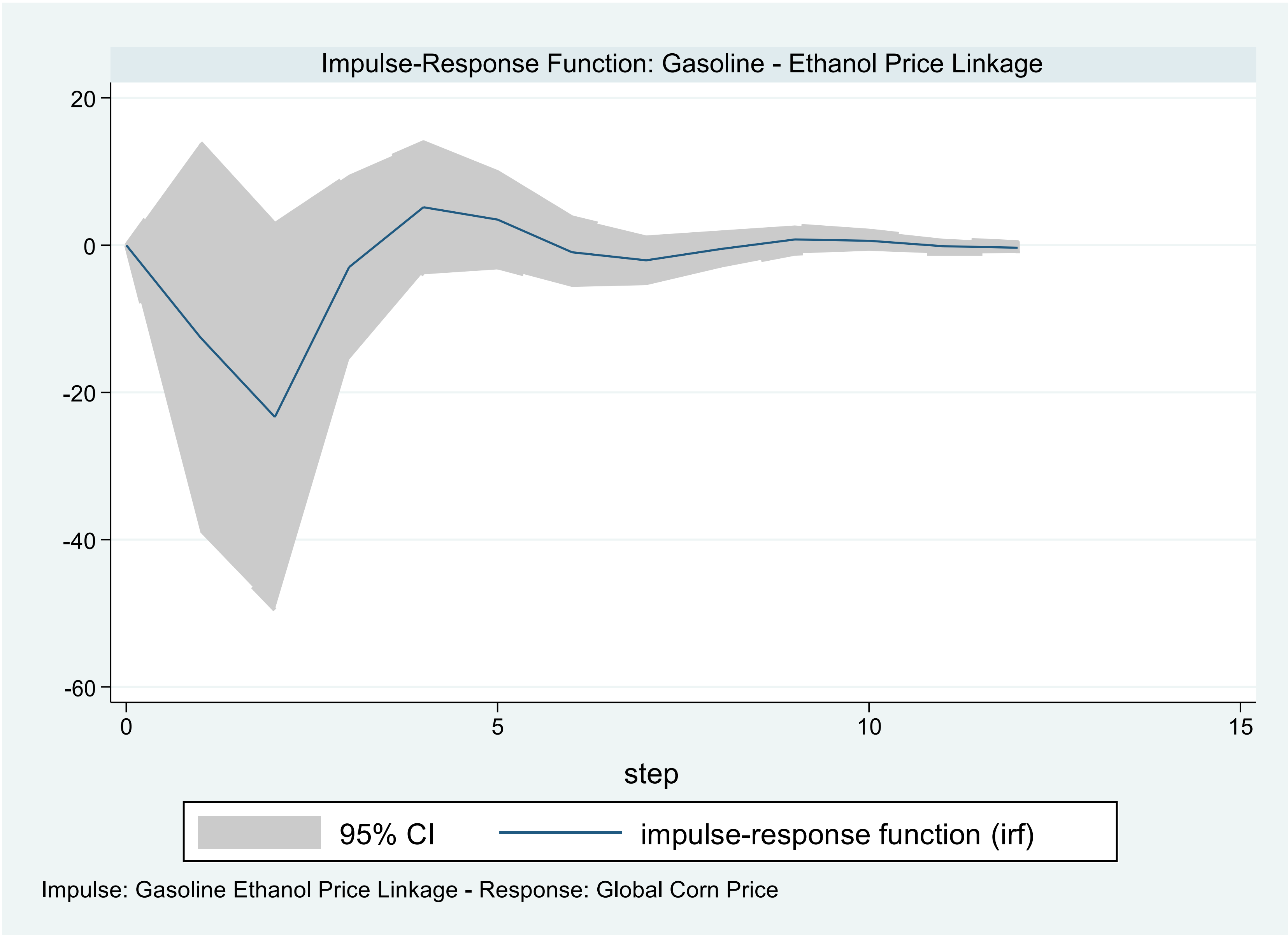
Impulse-Response Function: Global Corn Output
.2
.1
0
-.1
-.2
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Global Corn Output - Response: Global Corn Price

Figure A3



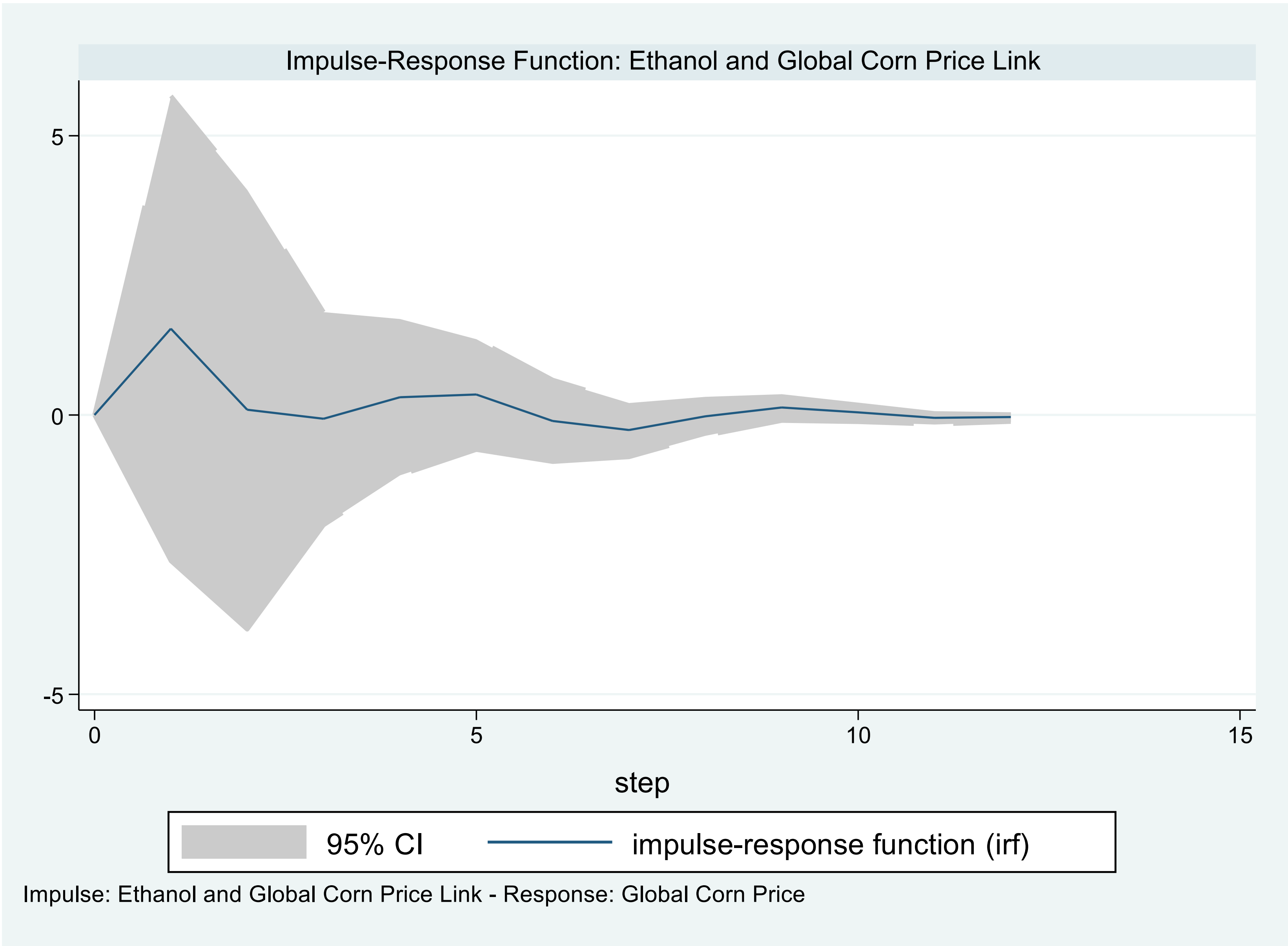
Impulse-Response Function: Global Corn Stocks
.4
.2
0
-.2
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Global Corn Stocks - Response: Global Corn Price

Figure A4



Impulse-Response Function: Gasoline - Ethanol Price Linkage
20
0
-20
-40
-60
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Gasoline Ethanol Price Linkage - Response: Global Corn Price

Figure A5


Impulse-Response Function: Ethanol and Global Corn Price Link
5
0
-5
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Ethanol and Global Corn Price Link - Response: Global Corn Price

Appendix B – Global Soybean Model

Johansen Test for Cointegration

Soybean Model
Trend: Constant
Sample: 2007–2016
Lags: 2

Table B1

Maximum Rank	Parms	LL	Eigenvalue	Trace Statistic	5% Critical Value
0	30	$1456.4323	$	236.3359	68.52
1	39	$1422.9744	0.44400	169.4203	47.21
2	46	$1394.642	0.39168	112.7555	29.68
3	51	$1371.6967	0.33139	66.8648	15.41
4	54	$1351.9811	0.29241	27.4335	3.76
5	55	$1338.2643	0.213388		

Figure B1

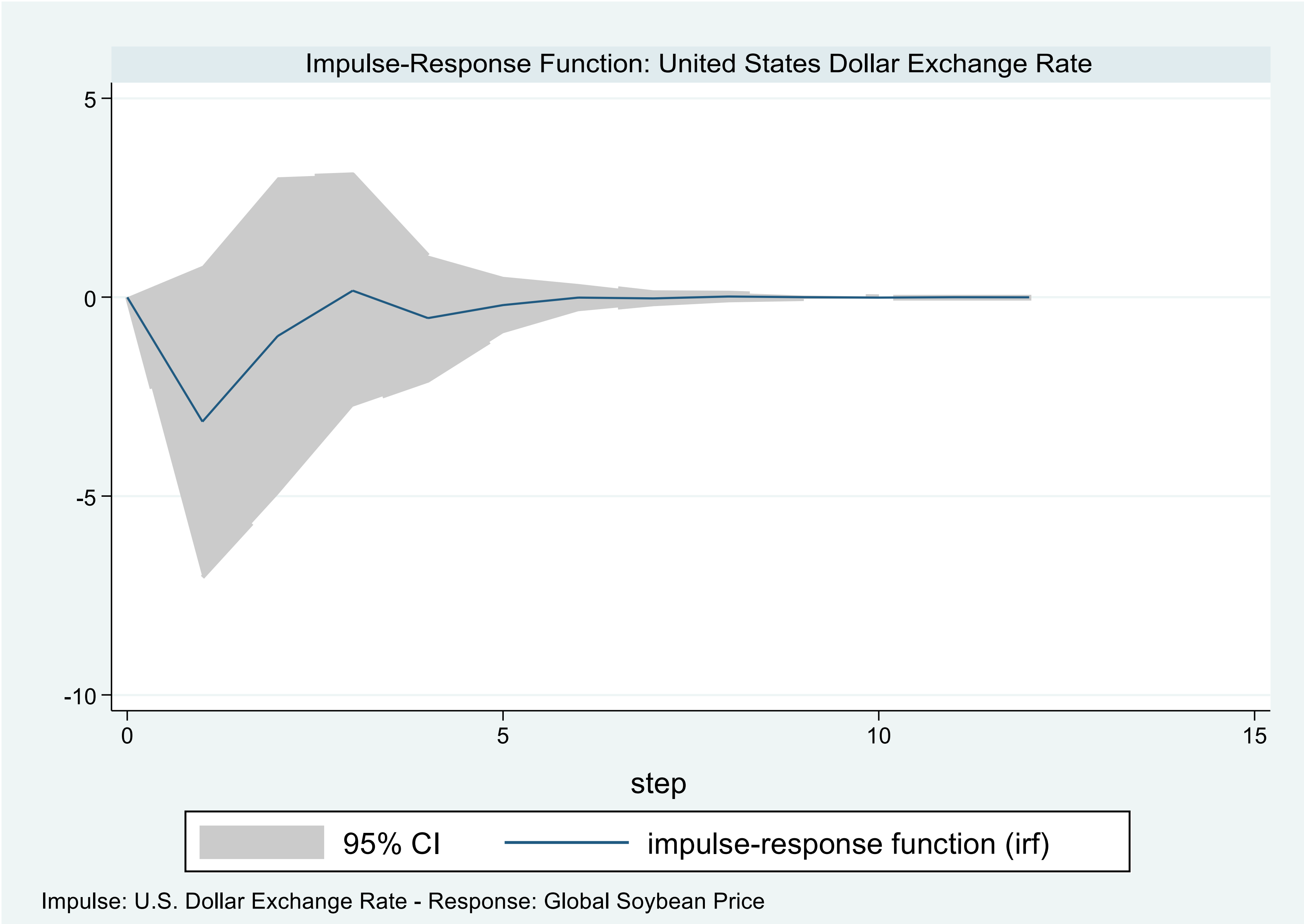
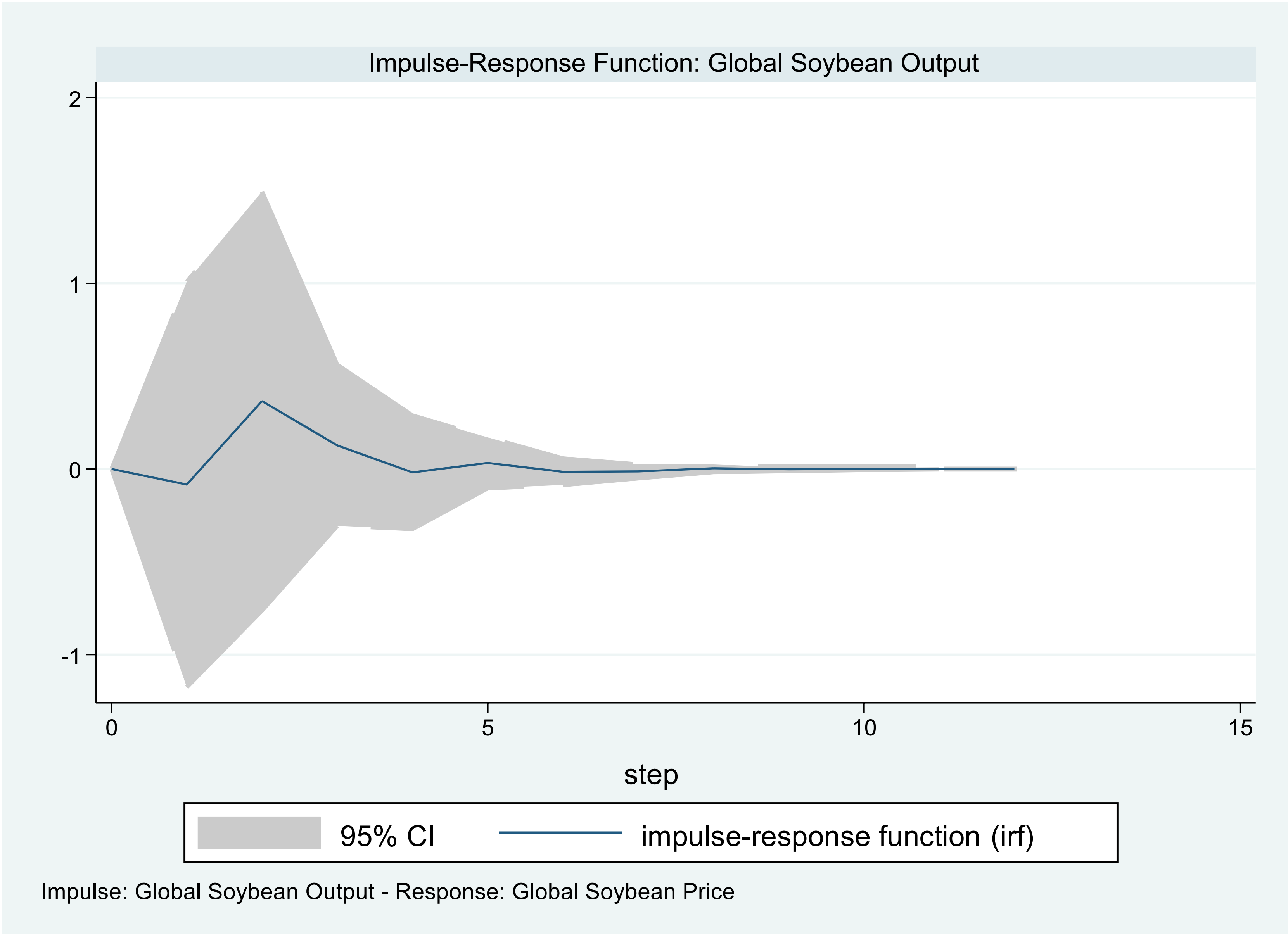

Impulse-Response Function: United States Dollar Exchange Rate
5
0
-5
-10
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: U.S. Dollar Exchange Rate - Response: Global Soybean Price

Figure B2



Impulse-Response Function: Global Soybean Output
2
1
0
-1
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Global Soybean Output - Response: Global Soybean Price

Figure B3

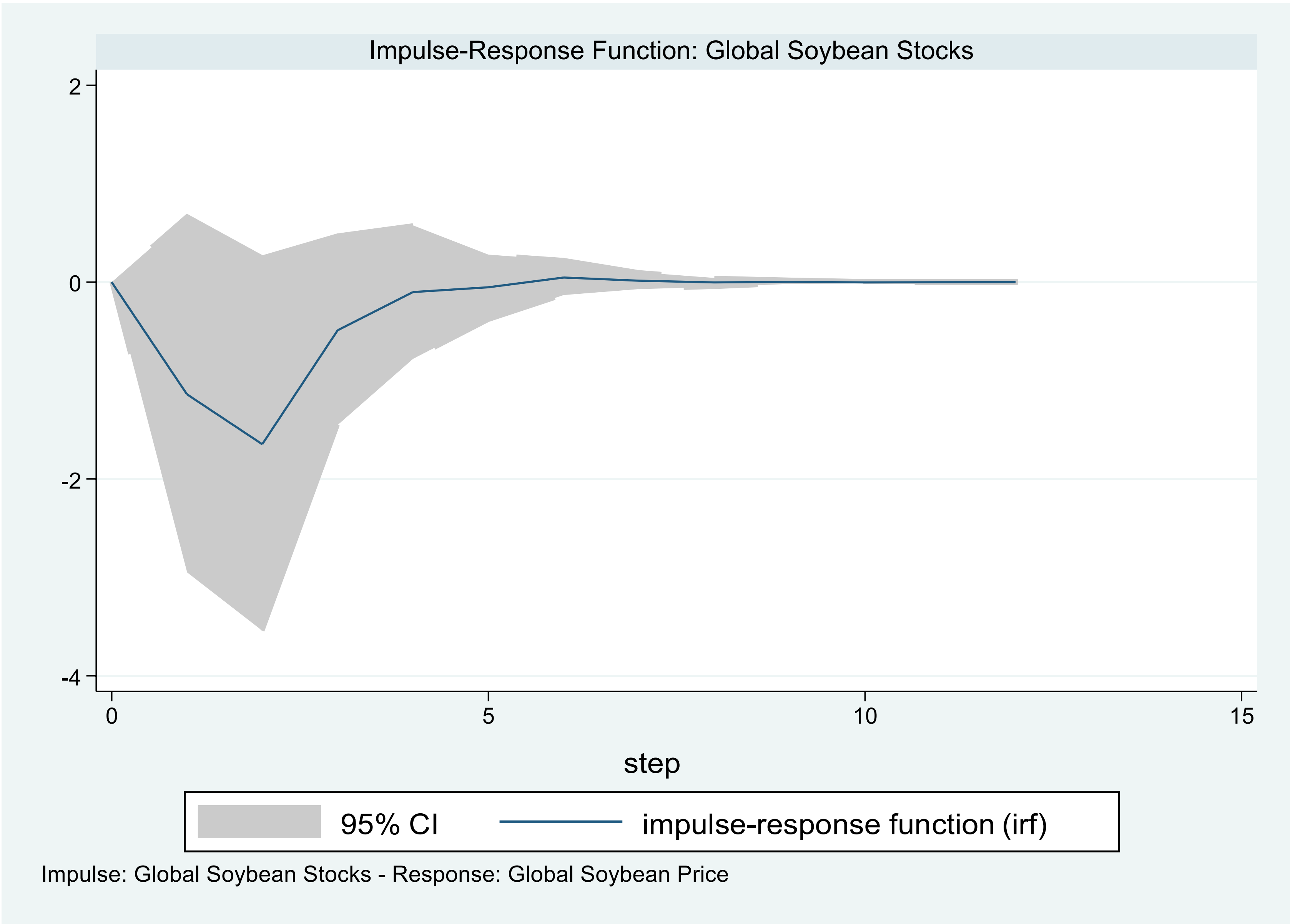

Impulse-Response Function: Global Soybean Stocks
2
0
-2
-4
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Global Soybean Stocks - Response: Global Soybean Price

Figure B4

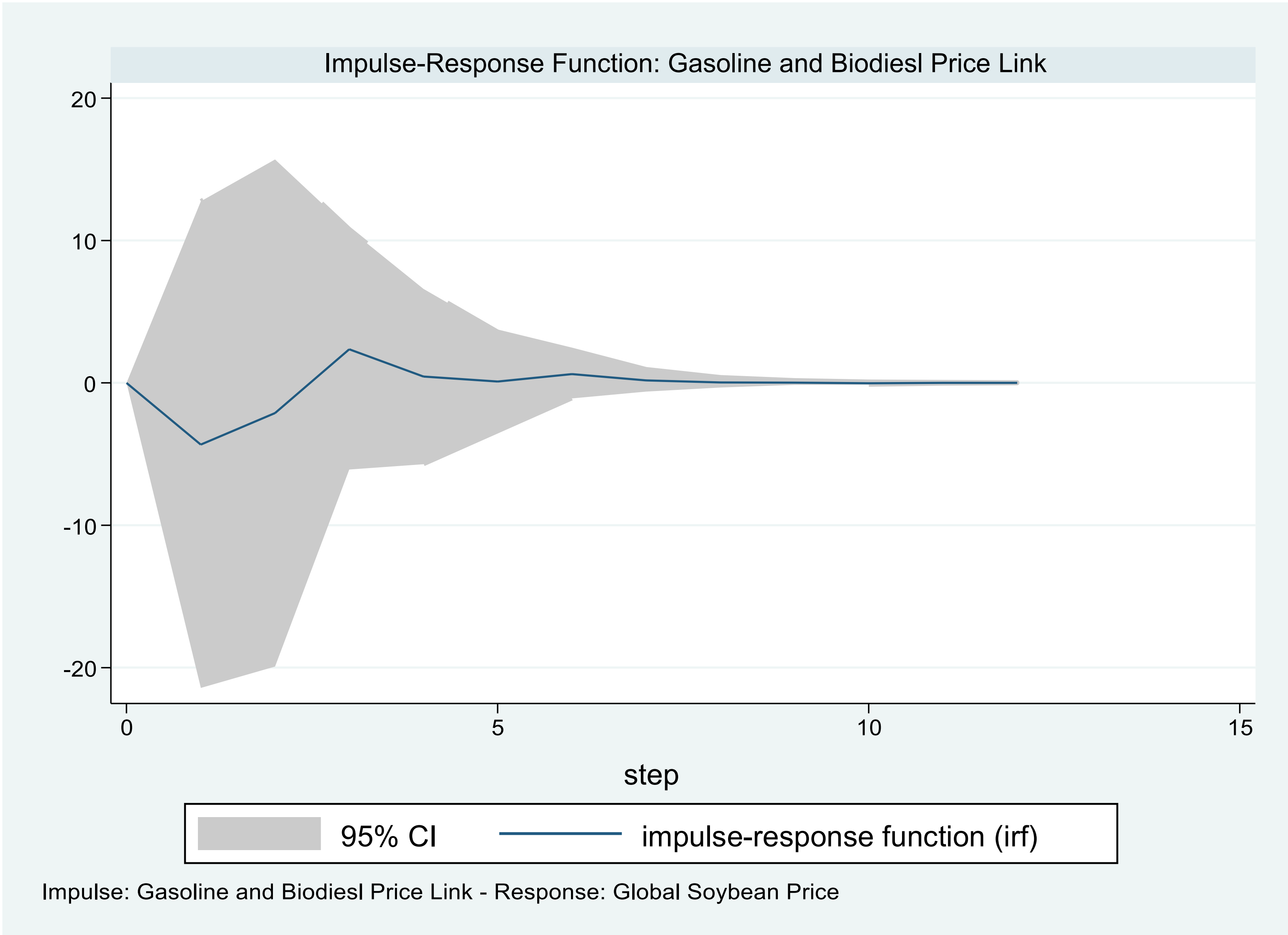
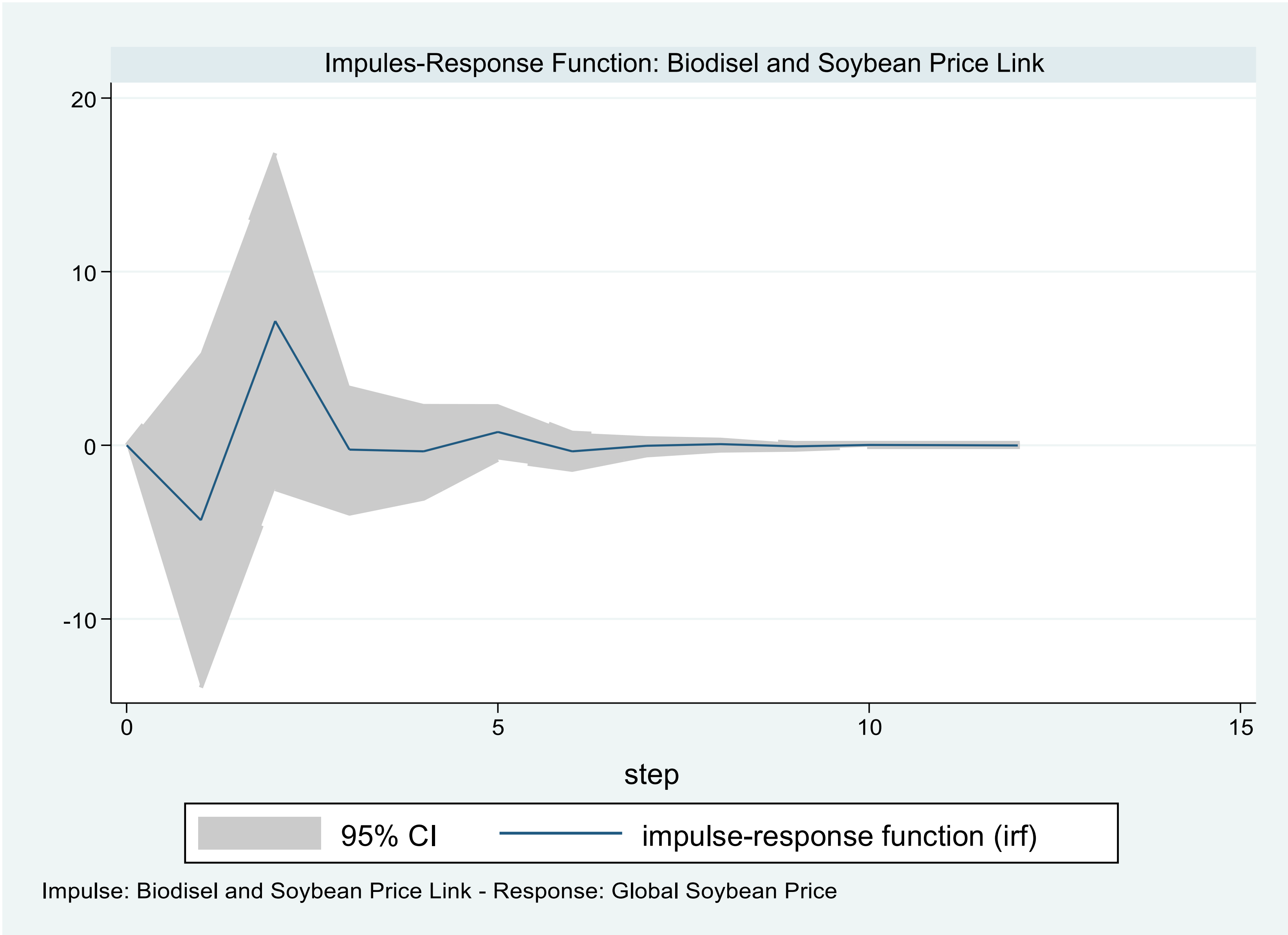

Impulse-Response Function: Gasoline and Biodiesl Price Link
20
10
0
-10
-20
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Gasoline and Biodiesl Price Link - Response: Global Soybean Price

Figure B5


Impules-Response Function: Biodisel and Soybean Price Link
20
10
0
-10
0
5
10
15
step
95% CI
impulse-response function (irf)
Impulse: Biodisel and Soybean Price Link - Response: Global Soybean Price

Augmented Dickey Fuller Test Soybean Model – Dollar Exchange Rate

Table B2

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.372	-3.561	-2.772	-2.498
11	-3.299	-3.561	-2.798	-2.523
10	-3.477	-3.561	-2.824	-2.547
9	-3.209	-3.561	-2.849	-2.571
8	-3.875	-3.561	-2.873	-2.594
7	-4.087	-3.561	-2.897	-2.615
6	-4.724	-3.561	-2.919	-2.636
5	-3.494	-3.561	-2.94	-2.655
4	-3.706	-3.561	-2.96	-2.674
3	-3.874	-3.561	-2.978	-2.69
2	-4.857	-3.561	-2.995	-2.706
1	-6.107	-3.561	-3.01	-2.719

Augmented Dickey Fuller Test Soybean Model – Global Soybean Output

Table B3

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.822	-3.561	-2.772	-2.498
11	-4.204	-3.561	-2.798	-2.523
10	-4.249	-3.561	-2.824	-2.547
9	-4.957	-3.561	-2.849	-2.571
8	-4.466	-3.561	-2.873	-2.594
7	-4.276	-3.561	-2.897	-2.615
6	-4.407	-3.561	-2.919	-2.636
5	-5.504	-3.561	-2.94	-2.655
4	-6.01	-3.561	-2.96	-2.674
3	-6.466	-3.561	-2.978	-2.69
2	-8.364	-3.561	-2.995	-2.706
1	-8.545	-3.561	-3.01	-2.719

Augmented Dickey Fuller Test Soybean Model – Global Soybean Stocks

Table B4

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.084	-3.561	-2.772	-2.498
11	-3.305	-3.561	-2.798	-2.523
10	-3.479	-3.561	-2.824	-2.547
9	-3.446	-3.561	-2.849	-2.571
8	-3.59	-3.561	-2.873	-2.594
7	-3.575	-3.561	-2.897	-2.615
6	-3.185	-3.561	-2.919	-2.636
5	-4.741	-3.561	-2.94	-2.655
4	-4.716	-3.561	-2.96	-2.674
3	-4.359	-3.561	-2.978	-2.69
2	-6.746	-3.561	-2.995	-2.706
1	-7.262	-3.561	-3.01	-2.719

Augmented Dickey Fuller Test Soybean Model – Global Soybean Stocks

Table B5

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.934	-3.561	-2.772	-2.498
11	-4.963	-3.561	-2.798	-2.523
10	-3.15	-3.561	-2.824	-2.547
9	-3.631	-3.561	-2.849	-2.571
8	-3.891	-3.561	-2.873	-2.594
7	-4.141	-3.561	-2.897	-2.615
6	-4.197	-3.561	-2.919	-2.636
5	-3.931	-3.561	-2.94	-2.655
4	-4.13	-3.561	-2.96	-2.674
3	-4.482	-3.561	-2.978	-2.69
2	-5.286	-3.561	-2.995	-2.706
1	-6.209	-3.561	-3.01	-2.719

Augmented Dickey Fuller Test Soybean Model – Predicted Soybean Price

Table B6

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.631	-3.561	-2.772	-2.498
11	-3.091	-3.561	-2.798	-2.523
10	-3.301	-3.561	-2.824	-2.547
9	-4.278	-3.561	-2.849	-2.571
8	-4.761	-3.561	-2.873	-2.594
7	-5.121	-3.561	-2.897	-2.615
6	-4.102	-3.561	-2.919	-2.636
5	-4.479	-3.561	-2.94	-2.655
4	-4.549	-3.561	-2.96	-2.674
3	-5.089	-3.561	-2.978	-2.69
2	-5.583	-3.561	-2.995	-2.706
1	-6.705	-3.561	-3.01	-2.719

Augmented Dickey Fuller Test Soybean Model – Global Soybean Price

Table 7

Lags	Test Statistic	1% Critical Value	5%Critical Value	10% Critical Value
12	-3.393	-3.561	-2.772	-2.498
11	-3.236	-3.561	-2.798	-2.523
10	-2.821	-3.561	-2.824	-2.547
9	-3.78	-3.561	-2.849	-2.571
8	-4.436	-3.561	-2.873	-2.594
7	-4.97	-3.561	-2.897	-2.615
6	-4.069	-3.561	-2.919	-2.636
5	-4.341	-3.561	-2.94	-2.655
4	-4.387	-3.561	-2.96	-2.674
3	-4.973	-3.561	-2.978	-2.69
2	-6.004	-3.561	-2.995	-2.706
1	-5.913	-3.561	-3.01	-2.719

Forecast Error Variance Decomposition – Global Corn Model

Figure A6

Month	U.S. Dollar Exchange Rate	Global Corn Output	Global Corn Stocks	Predicted Ethanol Price	Predicted Corn Price	Global Corn Price
1	0.128284	0.001975	0.005376	0.015404	0.141485	0.707477
2	0.157382	0.003588	0.008743	0.018953	0.141542	0.669793
3	0.161225	0.013801	0.008512	0.034298	0.136666	0.645497
4	0.161027	0.014076	0.010166	0.034565	0.136329	0.643837

Forecast Error Variance Decomposition – Global Soybean Model

Figure B6

Month	U.S. Dollar Exchange Rate	Global Bean Output	Global Bean Stocks	Predicted Biodiesel Price	Predicted Soybean Price	Global Soybean Price
1	0.184722	2.80E.06	0.015145	0.025402	0.479796	0.294932
2	0.215713	0.012049	0.031493	0.023333	0.432521	0.284892
3	0.213355	0.012401	0.05452	0.022238	0.419787	0.277698
4	0.212745	0.012448	0.056715	0.023116	0.418124	0.276853